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NORMALIZED-DIFFERENCE SNOW INDEX (NDSI)

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Definition

Normalized-Difference Snow Index (NDSI) – normalized difference of two bands (one in the visible and one in the near-infrared or short-wave infrared parts of the spectrum) is used to map snow. Snow is highly reflective in the visible part of the EM spectrum and highly absorptive in the near-infrared or short-wave infrared part of the spectrum, whereas the reflectance of most clouds remains high in those same parts of the spectrum, allowing good separation of most clouds and snow.

Introduction

The NDSI has a long history. The use of ratioing visible (VIS) and near-infrared (NIR) or short-wave infrared (SWIR) channels to separate snow and clouds was documented in the literature beginning in the mid-1970s by Valovcin (1976, 1978) and also by Kyle et al. (1978). A considerable amount of work on this subject was conducted at, and published by, the Air Force Geophysics Laboratory (AFGL) (e.g., see Bunting and d'Entremont, 1982). The objective of the AFGL work was to discriminate snow cover from cloud cover using an automated algorithm to improve global cloud analyses. Later, automated methods that relied on the VIS/NIR ratio were refined substantially using satellite data, by Crane and Anderson (1984), Dozier (1989), and Rosenthal and Dozier (1996) for regional scales, and by Riggs et al. (1993), Hall et al. (1995, 2002), and Hall and Riggs (2007) for global snow-cover mapping. In this section, we provide a brief history of the use of the NDSI for mapping snow cover.

Band ratios used to discriminate snow and clouds

Results of an investigation of snow reflectance characteristics using data from Skylab Earth Resources Experiment Package (EREP) S192 multispectral scanner are presented by Barnes and Smallwood (1975). For the first time, satellite study of snow from the spectral range extending from the VIS to the IR (0.41–12.5 μm) was possible, and this paved the way for automated snow-cover mapping. Shortly thereafter, Valovcin (1976) at AFGL introduced the idea of using the ratio of radiance values in the VNIR (0.68–0.76 μm) and NIR or SWIR (1.55–1.75 μm) to provide a method to discriminate between snow cover and clouds. Kyle et al. (1978) used the ratio of the 1.6–0.754 μm channels to distinguish snow and clouds using a cloud physics radiometer with 0.754–1.64 μm channels. They also used an IR band to test for surface temperature further distinguished snow and clouds.

Additional work done at AFGL by Bunting and d'Entremont (1982) employed a 1.6 μm sensor flown on the Defense Meteorological Satellite Program (DMSP) Special Sensor C (SSC) to separate snow and clouds. They also used 11% reflectance to define the lower bound of reflectance for snow cover. Crane and Anderson (1984) reviewed the previous work, mainly conducted at AFGL, and employed the DMSP Operational Linescan System (OLS), which operated in the 0.4–1.0 μm and 8–13 μm range, along with SSC data (1.51–1.63 μm). They employed reflectances derived from the various sensors to map snow using a threshold technique.

More-sophisticated use of band ratios as applied with Landsat Thematic Mapper TM data was developed by Dozier (1987, 1989). The normalized difference of TM bands 2 (0.52–0.60 μm) and 5 (1.55–1.75 μm) was introduced in Dozier (1989). Dozier and Marks (1987) discuss automated snow mapping and threshold tests for shadowed snow, cloud, vegetation, and soil in sunlit areas.

With the anticipated launch of the Moderate Resolution Imaging Spectroradiometer (MODIS) at the end of the 1990s, a global snow-mapping algorithm needed to be developed that would perform automatically and not be computationally intensive. Using the heritage algorithms discussed above, Hall et al. (1995) coined the term normalized-difference snow index and outlined a snow-mapping algorithm that would be the basis of the MODIS standard snow-mapping product. The prototype algorithm, called Snowmap, used a normalized difference between MODIS band 4 (5.45–5.65 μm) and 6 (1.628–1.652 μm), as was done in Bunting and d'Entremont (1982), Crane and Anderson (1984), and Dozier (1989) using TM bands 2 and 5. The prototype MODIS algorithm also employed several spectral tests. A planetary reflectance $\leq$11% was a threshold test in which values $<$11% were mapped as "not snow," determined not to be snow.

The prototype MODIS snow-mapping algorithm was improved with additional spectral tests. One key modification is that the NDSI threshold was changed in forested areas based on results of a canopy reflectance model (Klein et al., 1998), using both the Normalized Difference Vegetation Index (NDVI) and NDSI in densely forested areas as determined from the NDVI test. A thermal mask was also included to remove erroneous "snow" in locations where snow is considered to be impossible. Small specks of erroneous snow that show up on an image may be due to sand. If the band 31 (10.780–11.280 μm) temperature is >283 K, then a pixel is considered "not snow." This type of thermal test of surface temperature had previously been used by Kyle et al. (1978) and Romanov and Gutman (2000). The standard MODIS cloud mask is also employed as an input to the snow algorithm.

Following the 1999 launch of the MODIS on the Terra spacecraft, the snow algorithm was modified several times, but the NDSI has remained the basis of the algorithm. The current algorithm is Version 005 (see Riggs et al., 2006).

Summary

The term normalized-difference snow index (NDSI) was coined by Hall et al. (1995), but the NDSI technique already had nearly a 20-year heritage as similar methods using various visible and near-infrared bands had been used since the mid-1970s to map snow and separate snow from most clouds. Following the launch of the MODIS in 1999, the NDSI approach to mapping snow cover became automated using an algorithm that utilizes the NDSI along with a variety of threshold tests.

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